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Original Research

Morphological examination and clinical significance of the tibialis posterior: A cadaver study

The morphology of the tibialis posterior

Berin Tugtag Demir[1], Murat Uzel[2], Ummuhan Yagmurkaya[3], Dilara Patat[1], Burak Bilecenoglu[1]
[1] Department of Anatomy, Faculty of Medicine, Ankara Medipol University, Ankara
[2] Department of Orthopaedics and Traumatology, Faculty of Medicine, Kocaeli University, Kocaeli
[3] Department of Physiotherapy, Ankara Medipol University, Ankara, Turkey

Abstract

Aim: The purpose of the study was to characterize the morphology of the tibialis posterior muscle, and to determine the relationship of the muscle with the flexor digitorum longus tendon when planning surgical procedures in the region.

Material and Methods: The study was carried out by performing tibialis posterior muscle dissection in 30 lower (40-65 age range, 18 males/12 females) extremities. In the study, muscle and tendon sizes, tendon diameter, distances to reference points, origin and insertion regions were measured for length, and morphological description of the attachment area.

Results: It was found that the tendon diameter was 13x5 mm at the insertion, 9x4 mm at the end of muscle fibers, and 10.4x4.4 mm at the medial malleolus level. As a result of the dissections, it was determined that the tibialis posterior tendon crossed with the flexor digitorum longus tendon approximately 75.0±21.0 mm proximal to the lower end of the medial malleolus.

Discussion: We hold the belief that our cadaver study will guide clinicians.

Keywords

Tibialis Posterior, Flexor Digitorum Longus, Cadaver, Tendon Transfer

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Corresponding Author: Berin Tuğtağ Demir, Department of Anatomy, Faculty of Medicine, Ankara Medipol University, 06050, Altındağ, Ankara, Turkey.

E-mail: berintugdemir@gmail.com P: +90 553 470 65 96

Corresponding Author ORCID ID: https://orcid.org/0000-0001-8301-9257

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Introduction

The tibialis posterior (TP) muscle, located in the posterior-deep compartment of the leg, Designer from the fibula and interosseous membrane, 1/3 proximal to the tibia (below the soleal line). When the tendon of the TP descends 1/4 distal in the posterior compartment, it runs anterior to the flexor digitorum longus muscle (FDL) and enters the fibrous tunnel behind the medial malleolus (MM). The TP tendon is larger and more anterior than FDL's tendon when it passes behind the MM. Whilst the TP attaches mainly to the navicular and medial cuneiform, it can also partially insert into the intermediate/ lateral cuneiform and the cuboid bone [1,2].

The chief task of TP is to perform the varus movement of the foot and to protect the longitudinal medial arch of the foot thanks to the multiple connections of the TP and its tendon on the plantar surface of the foot [3,4]. It is evident that the TP gains clinical importance due to its role in walking and protecting the medial longitudinal arch. In the literature, there have not been enough studies focusing on the morphometric properties of the TP muscle and tendon so far [2-5]. Additionally, a few studies were found to examine the relationship between TP and FDL in the literature. Thereupon, it is thought that dwelling upon the morphological features of the muscle and tendon of the TP will cast light on the adoption of clinical approaches in orthopedic surgery (tibia lower-end deformities, isolated medial malleolar approach, medial incision).

Material and Methods

Permission was obtained from Kahramanmaraş Sütçü İmam University Ethics Committee for Non-Pharmaceutical Practices. (date: 25.06.2013/No: 2013/12-5). TP muscles in 30 lower extremities (40-65 age range, 18 males / 12 females, since 2 out of 32 lower extremities had TP deformation, the study was carried out with total 30 samples without side) which were supracondylar amputated for medical reasons were dissected. It is worth noting here that lower extremities previously operated below the level of the knee joint or impaired muscle/tendon structure were excluded from the study.

Lower extremity dissection was performed according to the predetermined protocol [5]. The dissection was started by removing the skin and the superficial fascia, which runs from the posterior part of the leg to the gastrocnemius. Afterwards, the foot was held in inversion in order to document the course of the TP tendon attaching at the medial and plantar aspects of the foot. After making visible the superficial muscles in the posterior and anterior of the leg, most of the deep-posterior compartment fascia and the TP and FDL muscles' bellies were dissected, starting from the proximal of leg. The tendon courses of both muscles and around the medial malleolus were dissected in an extremely meticulous fashion. Subsequently, the TP tendon was removed at the osseous insertions.

Following the dissection, the following morphological features of TP were evaluated (Figure 1):

• Diameters of the TP tendon in the origin (myotendinous junction), inferior tip of MM, tibiotalar joint (TTJ) and insertion regions, and the distance between these points and the insertion point of the tendon

• Diameters of TP muscle fibers in TTJ and MM and distance of muscle fibers from insertion

• Morphological features of the TP-FDL intersection (Figure 2).

Statistical analysis

Statistical analysis was performed using SPSS for Windows 21 software. Results are presented as mean and standard deviation unless otherwise stated. The Shapiro-Wilk test was applied to control the normality of the data distribution. As the data were not normally distributed, the Mann-Whitney test was used to compare the TP parameters and anthropometric measurements between the genders, respectively. $P<0.05$ was accepted as statistical significance.

Ethical Approval

Ethics Committee approval for the study was obtained.

Results

In all dissections, it was determined that the TP was attached to the navicular (82%) and medial cuneiform (18%). The presence of addition/accessory tendons extending from the TP to other structures was not witnessed. As the TP tendon passed just below the MM tubercle, there was a thin septum between it and the FDL tendon (Figure 3).

Between the medial malleolus and the sustentaculum tali calcanei, the tendon sheath of the TP tendon can be identified [a, a1]. The first TP tendon insertion is located at the plantar aspect of the navicular bone [b, b1]. (TP: Tibialis posterior, FDL: Flexor digitorum longus, FHL: Flexor hallucis longus, NB: navicular bone, MCB: Medial cuneiform bone, MM: medial malleolus)

It was found out that the diameter of the TP at the TTJ level was 10x4 mm, the diameter at the end of the muscle fibers was 9x4 mm, and the diameter at the insertion was 13x5 mm. Another finding was pertinent to the fact that the width of the insertion of the TP tendon in men (13±4 mm) was higher than in women (10±1), and this difference was statistically significant (p=.04). In addition, the width of the tendon at the end of the muscle fibers was wider in men (p=.03).

To this end, these results were evident (Table 1):

• Mean distance between the initiation of the TP tendon and the MM,

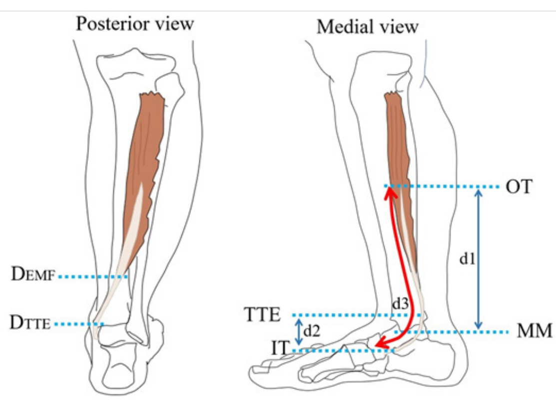

Figure 1. Morphometric measurement of the tibialis posterior muscle (DEMF: Diameter of the tendon at the end of the muscle fibers; DTTJ: Diameter of the tendon at the level of the tibiotalar joint; OT: Origin of tendon; MM: Medial malleolus, TTJ: Tibiotalar joint; IT: Insertion of tendon; d1: distance between the starting point of the TP tendon and MM; d2: distance between the end of the tendon and TTE; d3: Total length of the tendon).

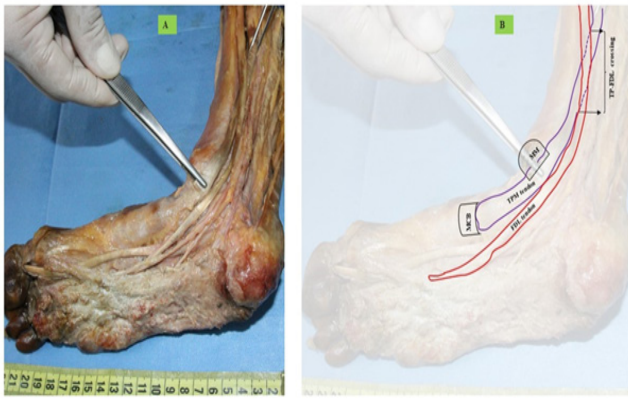

Figure 2. Tibialis posterior / Flexor digitorum longus relationship and crossover (TP: Tibialis posterior muscle, FDL: Flexor digitorum longus muscle).

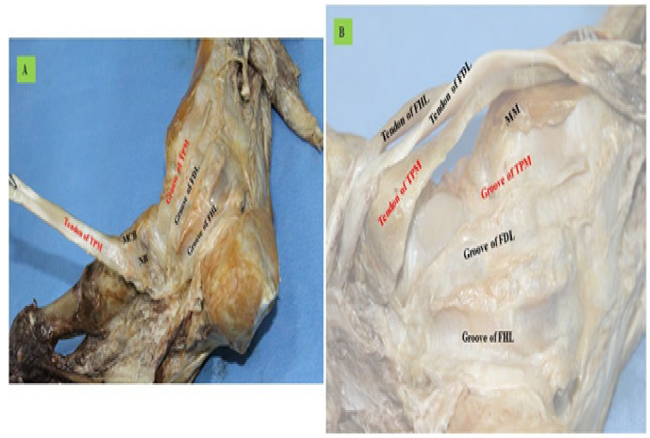

Figure 3. Deflected and tensioned tibialis posterior tendon.

Table 1. Features of the tibialis posterior tendon.

	Total	Male (Min-Max)	Female (Min-Max)	p
Tendon width at TTJ level	10.42±2.55 (5.00-18.00)	10.22±1.16 (9.00-18.00)	10.80±4.10 (5.00-18.00)	.74
Tendon thickness at TTJ level	4.46±1.10 (3.00-7.00)	4.38±.97 (3.00-7.00)	4.60±1.34 (2.50-6.00)	.81
Tendon width at insertion	13.00±4.06 (8.00-22.00)	13.77±4.31 (9.00-22.00)	10.60±1.23 (8.00-19.00)	.04*
Tendon thickness at insertion	5.00±1.46 (3.00-7.00)	5.11±1.45 (3.00-6.00)	4.80±.83 (3.00-7.00)	.56
Tendon width at the end of the muscle fibers	8.75±1.99 (5.00-11.00)	9.38±1.78 (5.00-11.00)	7.60±1.34 (5.00-9.00)	.03*
Tendon thickness at the end of the muscle fibers	4.17±1.02 (3.00-6.00)	4.11±1.13 (3.00-6.00)	4.30±1.89 (3.00-5.50)	.61
Distance from the MM of the point where the tendon begins in the muscle	16.87±4.03 (7.00-29.00)	17.13±4.59 (7.00-29.00)	16.40±.82 (13.00-21.00)	.56
Tendon insertion TTJ distance	16.37±3.80 (10.00-28.00)	15.94±4.62 (10.00-28.00)	17.15±1.41 (16.00-21.00)	.31
Distance from tendon origin to insertion	20.35±4.91 (9.00-32.00)	20.90±1.24 (9.00-32.00)	20.05±5.94 (18.00-24.50)	.22

TTJ: Tibiotalar joint, MM: Medial Malleolus

Table 2. Features of the tibialis posterior muscle's fibres.

	Mean	Male	Female	p
Muscle fibers from MM	5.32±1.32 (3.00-8.00)	5.55±1.21 (3.50-8.00)	4.90±1.46 (3.30-7.20)	.21
Muscle fibers from TTJ	4.42±1.06 (2.50-6.00)	4.66±.55 (3.00-6.00)	4.00±1.22 (2.50-6.00)	.16
From the insertion of muscle fibers	9.64±1.67 (7.50-15.00)	9.94±1.86 (7.50-15.00)	9.10±1.14 (7.50-10.50)	.13

TTJ: Tibiotalar joint, MM: Medial Malleolus

Table 3. Results of the tibialis posterior – flexor digitorum longus cross.

	Mean (Min.-Max.)	Male (Min.-Max.)	Female (Min.-Max.)	p
TP/FDL cross start	4.51±1.04 (3.00-7.70)	4.61± .99(3.50-7.50)	3.50± .62 (3.00-4.50)	.002*
TP/FDL cross finish	8.58±1.10 (7.00-11.00)	8.83±1.07(7.00-11.00)	7.75± 1.03(7.00-9.50)	.021*
Total muscle+tendon length	38.21±3.66 (32.00-48.00)	39.94±3.47 (34.00-48.00)	35.10±3.10 (32.00-44.00)	.001*

TP: Tibialis posterior, FDL: Flexor digitorum longus

• Distance between the end of the tendon and the TTJ,
• The distance between the origin points of the tendon and insertion. Eighty-two percent of navicular TP insertions were located on the plantar aspect. The TP tendon usually showed oval and o-shaped attachments at its attachment to the navicular bone.

There was no statistically significant difference in gender between the distance of muscle fibers from MM to TTJ and insertion (p>0.05) (Table 2).

It was figured out that the total length of TP in men was higher than in women (p<0.05) (Table 3).

The cross between the TP and the FDL occurred at the posteromedial edge of the tibia almost 45.1-85.8 mm proximal to the MM. Thus, a distance of about 40-50 mm TP was proximal to the FDL. A statistical difference was detected in the TP-FDL cross according to gender (p<0.05) (Table 3).

Discussion

The course of TP tendon lies posterior to the axis of the tibiotalar joint and medial to the axis of the subtalar joint, allowing the muscle to act as a plantar flexor and invertor of the foot. During normal gait, the TP acts to invert the hindfoot, causing the midtarsal joints to lock [4-7]. According to this theory and applying tendon transfer principles, it has been postulated that the FDL tendon, should be placed as far as possible from the subtalar joint axis (at the medial aspect of the navicular bone) in order to maximize leverage in FDL tendon transfer. Nevertheless, following the anatomical course of the TPT, the first fulcrum of the TP tendon is the medial malleolar groove, and the second fulcrum is the navicular tuberosity. Our study showed that the TP tendon is primary attached to the plantar aspect of the navicular bone insertions. With this anatomical knowledge, we claim that the navicular tuberosity acts as an additional pivot point of the TPT to ease the inversion of the foot.

Willegger et al., in their study on 41 cadavers, highlighted that the TP was attached to the navicular in all samples (100%); in addition, they reported the involvement of the lateral cuneiform, medial cuneiform, metatarsal I-V, cuboid, middle cuneiform, calcaneus [8]. Park et al. suggested that a wider adhesion occurred in the insertion of the navicular bone in males than in females [2]. Eighty-two percent of navicular TP insertions were located at the plantar aspect in our study. The TP tendon usually showed oval and o-shaped attachments at its attachment to the navicular bone. The muscle's tendon ended at the insertion point in the form of a thick bundle. Our research then announced that the males have insertion points wider than females as the research of Park et al. [2] (Table 1). We are of the opinion that this particular situation may be due to the greater muscle strength in men.

Tendon transfer, with dissimilar dorsal attachment sites above the foot (tendon-bone, tendon-tendon), is one of the most frequently applied procedures, at the same time, it is also considered the gold standard for successful surgery [5,9]. Furthermore, tendon transfer is also recommended in cases where direct surgical repair is not possible in nerve lesions and when nerve surgeries prove unsuccessful. As a result of restoring the foot dorsiflexion with tendon transfer, functional gains close to normal are observed in patients [7,10]. Considering the ankle extensors and evertors, the TP tendon will provide the ideal strength to gain dorsiflexion by eliminating the dominant inversion force. In a study, it was propounded that the TP tendon is stronger than the tendons of other muscles in the leg region [4,11]. This functionality of the TP tendon allows for a versatile treatment through minimizing morbidity. If a person both needs more power than TP's support and the pes planus deformity that may develop as a consequence of removal or loss of the TP tendon, FDL can help with this [4,5,7,12]. Therefore, in our viewpoint, perceiving not only the TP but also the TP-FDL relationship and the distance of the cross point to the land marker points in tendon transfer is extremely valuable in terms of surgical data.

The TP tendon transfer from the interosseus membrane of the leg is among the commonly performed methods. Deciding on the dimension of the space to be opened in the membrane is extremely important for preventing muscle and tendon compression [13]. One of the factors that will determine the incision dimension in the membrane is the tendon diameter. Wagner et al. declared that the tendon diameter was 19.47 mm at 15 cm proximal to the MM tip [13]. They suggested that it would be better to open a membrane space 5 cm or 2.5 times the tendon diameter, to reduce possible complications. Xu et al, in their study on 25 cadavers, shared that a 10 cm space to be opened starting from 5 cm above the distal end of the MM would be sufficient for subcutaneous TP transfer [14]. In our study, tendon width at the end of the muscle fibers was measured larger in men than in women (Table 1). In this context, we believe that gender should be taken into account while performing the tendon transfer, and that men should act more proximal than women and open a larger space. Besides, it is deemed necessary to choose a distant place to gain a mechanical advantage, and at this point, the TP tendon length gains a particular importance [6]. Whereas the tendon's function determines the position related to the joint, the distance to the joint determines the lever part of the force that can apply across the joint [4]. The mean TP muscle and tendon length meant that the total TP length in males was longer than in females.

TP tendon lesions usually occur at the level of the MM and 2-3 cm proximal to the insertion point in the navicular bone [15]. It has been italicized that TP tendon dysfunction is one of the most significant problems observed nominally in amateur athletes, and even the distal regions of young athletic individuals are very usual regions where the TP tendon injury is seen [15]. One of the significant parameters in tendon transfer is tendon length. The second incision should be as proximal as possible to ensure maximum tendon length. At the same time, muscle-related injuries should be avoided [6]. Thamphongsri et al. suggested that the anterior transfer of the TP tendon should occur with an incision above 7.1 cm from the MM in men and 6.4 cm in women in their study on 45 cadavers [6]. They concluded that with this incision, the root would not be damaged, and the longest movable tendon could be obtained. In our study, there was no statistically significant difference between the distance of muscle fibers from MM and insertion and gender.

The FDL is one of the long flexor muscles in the leg and foot. The muscle starts from the posterior surface of the tibia, just below the baseline of the femur, medial to the TP, and the fascia covering the TP. It inserts into a separate fascial compartment with a tendon that curves behind the MM with the TP [16,17]. There was a thin septum between the FDL tendon when the TP tendon passed just under the MM tubercle as in our study (Figure 1). In this study, the TP crossed the FDL at the lower end of the medial malleolus at a minimum of 30-77 mm proximal. This cross ended after moving below the FDL at a maximum of 70-110 mm proximal to the MM.

FDL tendon transfer is frequently used to reconstruct the TP in TP dysfunction. The location of the FDL and its contiguity to the TP has also directed surgeons to the FDL respecting accessibility [3]. Knowing the level of the TP-FDL cross will basically eliminate possible TP-FDL confusion during the surgical intervention and will provide guidance toward preventing probable damage. In our study, TP's cross differed between the sexes. In summary, it has been found that this difference in TP-FDL cross distance should be known in surgical interventions to be performed on men and women.

TP thickness is known to increase in degenerative processes. It is important to know the normal thickness of the tendon and normal appearance for monitoring pathological conditions and processes. It is necessary to take into account the size of the muscle tendon unit and the tendon dimensions that we specifically evaluate and to take into account the variables such as height, lengths of the lower extremity, leg and foot, weight, side, age, gender, or activity level that can be effective in determining its dimensions and its 3-dimensional placement. During the surgical planning of the TP tendon transfer, the varying dimensions and placement of the tendon at different points are considered in three dimensions. This information is very valuable in determining the location and size of skin incisions, tenotomies and tunnel to be made at interosseous membrane for tendon transfer.

Conclusion

We tried to provide detailed information on the structure of the TP in a limited number of cadavers. Normal function is better understood from the detailed three-dimensional structure of the TP muscle and tendon. Knowing this allows comparison with the structure and functions of other tendons. This enables the recognition of structural changes and the understanding of their results. It orients the skin and other soft and bone tissue applications for the purpose of the operation in treatment planning. For this purpose, larger and more comprehensive cadavers, diagnostic imaging and clinical studies are needed.

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Scientific Responsibility Statement

The authors declare that they are responsible for the article's scientific content including study design, data collection, analysis and interpretation, writing, some of the main line, or all of the preparation and scientific review of the contents and approval of the final version of the article.

Animal and human rights statement

All procedures performed in this study were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki Declaration and its later amendments or comparable ethical standards. No animal or human studies were carried out by the authors for this article.

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Conflict of interest

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